I have received the May number of the 'Annals of the Lyceum of New York' (vi. 35), containing a figure and description of the animal of *Rotella* made by the Rev. S. B. Fairbank of Bombay, and transmitted by him to the late Professor C. B. Adams.

Mr. Fairbank describes the lobe on the right side of the body, which is an extension of the front end of the lateral fringe, as a lobe probably "of the mantle which partly clings to the shell, but does not at all envelope it;" and he calls the veil "a siphon," and describes it "as a tube, the side being slit next the outer lip of the shell and filled with cilia; the cilia are tipped with black; sometimes they gather against the sides, so that you see the tube with a black rim, but usually they are disposed much as I have dotted them in the figure," that is to say, like the rays of a star. The lateral fringe, so constant in all the *Trochidæ*, is entirely overlooked in this figure and description. He observes that these shells are found where the water would leave them dry at least two hours each tide, just buried in the sand; when placed in water, they did not move about much, but only raised their siphons. As represented in the figure, the "siphon" greatly resembles the fringed siphonal tube of a bivalve shell; but I can scarcely conceive that the veil, as I observed it in the animal in spirit, could form such a complete tube. The part here called a siphon can only be considered as a great development of one of the fringed lobes which are found near the base of the tentacles of most *Trochidæ* and *Turbonidæ*, and which is a continuation over the head of the lateral membranes of these animals. It differs chiefly from the other *Trochidæ* in the rostrum not being developed, and the mouth consisting of a round opening under the base of the veil, and in the peculiar development of the frontal appendages.

XXI.—*On the Phosphorescence of some Marine Invertebrata.*

By M. A. De Quatrefages*.

[Concluded from p. 27.]

Second Part.—*General Observations on Phosphorescence.*

1. *Description of the Phænomenon.*—It would be useless to repeat here all the details given by travellers; I will confine myself to some remarks on my own observations.

The phosphorescence of the sea has appeared to me under two different forms:—1st, a result of scintillations more or less nu-

* From the Annales des Sciences Naturelles, vol. liv. 3rd series, as inserted in Silliman's American Journal of Science for July, 1853.

merous, always isolated, and not giving at all the idea of a liquid in itself luminous; 2nd, a general glow more or less uniform, the phosphorescent substance seeming to be dissolved in the water itself.

In both cases phosphorescence is equally a result from living animals directly emitting the light, but the species which produce the phænomenon are different.

A. I have often observed the first mode of phosphorescence on the western coasts of France, at points peculiarly exposed to the action of currents and waves. At Chausey, especially in the small channel called "le Sund de Chausey," I have seen very numerous and brilliant sparks brought out by each stroke of the oar. The track of the vessel seemed for a moment as if strewn with diamonds, but these sparks, always very brilliant, and appearing at the same instant, never communicated a general glow to the water. They remained completely isolated, and were distinct from the dark surface of the sea. At Brehat, St. Malo, and St. Vaast, I observed similar facts. The fishermen whom I questioned, all assured me that in these regions, the sea never presented a different appearance; the young men who had never left their native coasts, did not seem to understand my inquiries relative to a more general or diffused phosphorescence. M. Beautemps-Beaupré mentions his observing phosphorescence of this kind during one of the numerous excursions in which he was engaged, while making his magnificent Atlas of the coasts of France; but he cannot recall the exact locality. It was in the neighbourhood of St. Brieuc, and it may be that this single observation was made in some well-sheltered harbour, like the port of Paimpol.

If the sea itself rarely presents any remarkable phosphorescence in the localities of which I am about to speak, it is not so with the marine plants which are left by the tide. In some circumstances I have seen masses of the Fucus kindle up when seized a little rudely; but even then the light was in isolated points, which the eye easily distinguished from one another. In no case did the stalks or the leaves present the uniform tint of a metal at a white heat, and the water which ran out freely was never luminous. Moreover, the part of the beach which the sea had just left dry remained perfectly dark. At most, only a few sparks might be seen over a space of some extent.

Water drawn from the sea in the circumstances of which I speak, and when the scintillations were most numerous and most brilliant, often became suddenly obscure, or presented only some few luminous points, when the vase containing it was violently shaken, and these ordinarily disappeared instantly. This same water, poured out from some height, presented nothing peculiar.

Never, in the regions of which I speak, have I seen the waves breaking on a shore presenting the appearance described by travellers.

B. The second kind of phosphorescence I saw for the first time near Stromboli. Here the effects of the light were heightened by the dark hue of the waves around the volcanic cone; moreover, at Boulogne, and probably at Havre, Dieppe, Ostend, &c., this phænomenon is as complete and interesting as at Stromboli.

At Boulogne, the phosphorescence is apparent throughout the harbour, except where the waters of the Liane flow into it. It is diminished and perhaps destroyed towards the entrance, between the two dykes. It is very decided through the whole port properly so called, in the basin, and especially in the little cove named the "Parc aux huitres." The last locality, being very accessible, afforded opportunity for studying all the details of the phænomenon.

However favourable the circumstances for observation, the water when quiet was always perfectly dark; but the least movement drew forth light. A grain of sand cast upon the dark surface produced a luminous spot, and the undulations of the water were so many bright circles. A stone as large as the fist produced the same results in a more intense degree, and moreover each splashing occasioned a scintillation like that of a bar of iron at a white heat when struck upon an anvil. The entrance of a steamboat when the phænomenon was most apparent, was a magnificent sight, and recalled to mind the descriptions of travellers.

The "Parc aux huitres" was always bordered by a phosphorescent girdle, resulting from the incessant undulations of the sea, which reached the shore under the form of small waves; but in perfectly fair weather this light was too feeble to be distinguished at a distance. When these undulations were only 3 to 4 inches high, the ring might easily be seen from the pier, throughout its whole extent, and was especially marked in the inner part of this little harbour.

At Boulogne, as at Stromboli, these luminous waves, seen from a distance, presented a uniform tint of a pale dull white. It might be called almost a froth, resulting from the action of the waves against the shore; and seen at mid-day under the most favourable circumstances, that was all I could distinguish at a distance of seventy to eighty yards. In proportion as you advance the appearance changes; the waves, as they near the shore, seem crowned with a light bluish flame, which M. Becquerel has justly compared to that of a bowl of punch. When they strike, this brightness becomes whiter and more vivid. On reaching the bank, you often see these same waves under the aspect of

surges of melted lead or silver, strewn with an infinite number of bright scintillations, either brilliant white, or of a greenish tinge. The spectacle is then most beautiful, and after having witnessed it on a small scale, I understood the impression left on the minds of travellers who have seen it under the tropics, in all its magnificence. The following are the facts which I have myself witnessed.

The waves, in breaking on the nearly horizontal beach of the cove, although so little elevated, covered quite an extent, and the whole space presented a uniform and glowing tint, from which started out innumerable scintillations yet more brilliant, and of a bluish or greenish hue.

As the water became absorbed by the sand, a line more strongly luminous indicated its limit. This effect was especially marked in the little cavities which the shore presented, where the line formed concentric curves which diminished as these little basins were exhausted. On passing a long stick rapidly in the water, it presented in its whole length the appearance of a blade of silver.

The water taken up at random and poured out from a little height had exactly the appearance of melted silver, and it was the same in the slightest spray. It left upon the hands or clothes bright spots that were quite persistent. At one time, when, on a short excursion with M. Bouchard, a dog ran barking at us, we threw at him the contents of a small cup, and he fled in terror from what he seemed to take for fire, and troubled us no longer save at a distance. If we plunged our hands into the sea, when drawn out they were luminous all over, but after a few seconds they were marked only here and there with bright spots, whose brilliancy remained constant and without scintillations.

The bank recently left by the tide did not however show any trace of phosphorescence; yet at the least shock it became luminous, and seemed literally to glow under the steps of the observer. In some circumstances, wherever the foot rested on the sand or gravel, it seemed like burning coals beneath the tread; and this appearance was equally perfect, with more or less brilliancy, even to a distance of some inches.

The *Talitri*, so numerous on our sandy shores, and whose habits have gained for them from the fishers the name of sand-flea, become luminous by contact with the phosphorescent water, —a fact to be noted; for at first one might be led to imagine that they were the cause of the light. Nothing can be more curious than to see these sand-fleas leaping by hundreds, and appearing like the scattering of tiny sparks.

2. *The Animals that produce the phosphorescence in the two preceding cases.—a.* At Chausey, Brehat, St. Malo, and Saint Vaast,

I have many times sought for the cause of the bright sparks which I saw shining and then vanishing in darkness. In each case I met with living animals, and these animals were always Crustacea, Ophiura or Annelida. I usually found the first in the water drawn up either from channels or at some distance from the shore. The second were under stones, or in the masses of seaweed. It was especially to the Annelida that the Fucus owed its brilliancy.

These results explained all the circumstances of the first kind of phosphorescence. The Crustacea, whose movements are energetic and whose locomotion is extended, cannot easily be collected in sufficient quantity on a given point to have their scintillations appear like a uniform tint. Besides, there is nothing in the habits of the species I have examined to lead one to suppose that they are inclined to collect in numerous bands. The size of the *Ophiura* prevents such an idea with regard to them; and the smaller Annelid for a like reason cannot contribute to such a result. Thus the light produced by these different animals is always seen in points more or less near each other, but never really blended.

b. At Boulogne, on the contrary, we find this brilliant light exclusively due to *Noctilucæ*. With the most careful examination, I have never found in my vases a single Annelid, or a single phosphorescent Crustacean.

Many circumstances, some of which will be explained hereafter, illustrate the particular mode of phosphorescence of the sea, rendered luminous by the presence of these Rhizopodes. We will first notice their size and great number. The diameter of these *Noctilucæ* varies from about $\frac{1}{5}$th to $\frac{1}{3}$rd of a millimetre; but their abundance more than compensates for their minuteness, each drop of water, as observed by Suriray and M. Verhaeghe, containing one or more. The following calculations will give some idea of their vast numbers.

In taking up some water at random from a brilliant wave, I filled a tube about a decimetre in height. After being left a little time quiet, the deposition of *Noctilucæ* on the surface of the liquid was about $1\frac{1}{2}$ centimetre in thickness. Thus the *Noctilucæ* composed about $\frac{1}{7}$th of the phosphorescent water. Again, I took the water from the surface and filled a vessel about one-half. The whole height of the liquid was about 15 centimetres, and that of the mass of *Noctilucæ* was about 5 centimetres; here the proportion was about $\frac{1}{3}$. Finally, I remember that at False Bay, M. de Tessan found the proportion equal to $\frac{1}{2}$. From these numbers, it is easy to understand how the sea, rendered luminous by the *Noctilucæ*, may present a uniform brilliancy, irresistibly impressing the idea of a phosphorescent solution. When the

surface of the sea is tranquil, as in a well-protected harbour, the *Noctilucæ*, because of their small specific gravity, form a continuous bed, and the least movement is sufficient to cover that dark surface with a brilliant mantle. When the movement of a vessel at once breaks in upon this mass of *Noctilucæ*, and also calls out their simultaneous phosphorescence, the myriads of bright points lying in the trough of the wave present one universal hue. From a distance, the eye sees throughout a uniform brilliancy, and near by distinguishes only the most brilliant scintillations, or those thrown out by the animals at the immediate surface of the water. These brilliant waves are like so many nebulæ resolved by the eye only in part.

THIRD PART.—*Observations and Experiments on the Light of the* Noctilucæ.

[Instead of giving a full translation of this Part of the memoir, as has been done of the preceding, we offer here an abstract presenting in brief the conclusions of the author.—EDS.]

1. *In a sea rendered phosphorescent by* Noctilucæ, *the light proceeds only from the body of these Animals.*—This proposition is proved by direct microscopic examination; and by the water's being deprived of all light when the *Noctilucæ* are filtered out, and becoming luminous again when they are restored to it. In a tube of the seawater, the *Noctilucæ*, if left quiet, soon form a layer at the top of the liquid, and the light is confined entirely to this layer of the animals.

2. *The production of light is independent of contact with the air.*—The flashes of light that are produced with the breaking of every wave might seem to show that the access of the animals to the external atmosphere was essential to the result. But on the contrary, it is found by observation that in a vase of seawater containing the *Noctilucæ*, the bed of these animals that collects at the top of the base is equally luminous in every part.

3. *Colour of the light.*—When the *Noctilucæ* are in full vigour of life in quiet water, the colour is a clear blue. But on agitating the water, or in the waves of the sea, the light becomes nearly or quite white, or like silver sprinkled with some greenish or bluish spangles.

4. *Intensity of the light.*—M. de Tessan states that in some tropical seas, the phosphorescence is so bright from the breaking waves, that he could read ordinary type at a distance of fifteen paces. The light from the *Noctilucæ* cannot compare with this. At the head of the cove of the "Parc aux Huîtres" at Boulogne, it was not possible to tell the hour with a watch when the waves were breaking at the observer's feet. With a tube 15 millimetres

in diameter, in which the *Noctilucæ* formed a bed at the surface nearly 20 millims. thick, the figures of a watch face could be read; but strong agitation of the tube was necessary, and it was requisite to hold it close to the glass of the watch. Four to five teaspoonsfull of *Noctilucæ* were collected in a filter, and on producing the phosphorescence by this means the hour could be told at the distance of a foot.

5. *No disengagement of heat sensible to a thermometer accompanies the phosphorescence.*—This fact was established by placing the bulb of a thermometer in the Noctiluca water while it was quiet, and then giving it a shake to produce the phosphorescence. The experiment was varied in different ways.

6. *The light of the* Noctilucæ *may be produced over the whole surface of its body or only a part of it.*—After a violent agitation, the *Noctilucæ* retain the phosphorescence for some time, so that it may be studied at leisure. With a lens magnifying 6 to 8 diameters, it is easy to see that while some of the *Noctilucæ* are phosphorescent throughout, others are but partially so. In the figure Pl. VI. (fig. 7), one of the animals is light over its whole surface, and the other (fig. 8) only on opposite sides. With a lens of 10 to 12 diameters we find that the light often appears successively on different parts of the body. There is hence no circumscribed phosphorescent organ, as in the Lampyri, Elaters, and Pyrosomas*.

7. *The light is due to an infinite number of minute scintillations.*—Figure 9 of a part of a *Noctiluca* much magnified, represents the actual character of the phosphorescence. There is an immense number of points of light. With a lens of 20 to 30 diameters, the light is like an undefined nebula; but with a lens of 60 diameters it is partially resolved, and with 150 diameters, wholly, into its constituent spangles. Each luminous spot on the body is found to consist of a cluster of minute instantaneous scintillations, dense at the centre, and more scattered towards the circumference of the spot. Thus the same phænomena take place in the *Noctilucæ* as were observed by M. de Quatrefages in the *Ophiuræ* and *Annelida*. Each spot of light is resolvable into constituent points, and consists of evanescent scintillations.

* The *Noctiluca* (Pl. VI. fig. 6) has a depression on one side, and near the middle of this depression is the mouth. At the same place there is a moveable appendage as long as half the diameter of the animal. The body is perfectly transparent. The general envelope consists of two membranes distinguished with difficulty. The outer is excessively thin and like an epidermis; the inner is thicker, but without a trace of fibres. On compression the envelope acts like a bag full of liquid, and finally bursts. Numerous anastomosing and branching lines radiate from the mouth through the granulous interior.

8. *The light from the dead* Noctilucæ, *or from fragments of them, is identical with that from the vigorous living animal.*—When the light of the *Noctilucæ*, after frequent excitement, becomes white, it is also more fixed, and finally covers the whole body. From numerous experiments, M. de Quatrefages concludes, that this kind of light is evidence of disease, or of a decline of vigour, and when the light is universal, of death. Microscopic examinations make it apparent that in these cases the light is still made up of minute points, and it is evidently of the same nature with the light given out in active life.

9. *Precautions necessary to succeed in the preceding observations.*—The animals should be examined without the use of a compressor; and care should be taken in employing high powers, not to be deceived by the light proceeding from a point not quite in the focus, whose rays produce a confused image, as if the light were uniform instead of localized. This illusion is difficult to avoid with fragments, as they are apt to be folded, so as to bring more than one point of light in the focus at once.

10. *The phosphorescence is not the result of a kind of combustion.*—On taking a barometer tube nearly filled with mercury, putting in some seawater containing *Noctilucæ* (the water occupied 6 centimetres of the tube, and the bed of *Noctilucæ* was 3 centimetres thick), and then inverting it over mercury, a phosphorescence was produced of the pale white light which indicated approaching death, a consequence of the imperfect vacuum. After one hour and eighteen minutes, the phosphorescence had ceased, and could not be restored by shaking it. Oxygen gas was introduced without effect. It is probable that the phosphorescence, if due to combustion, would have been restored by the oxygen, as happens with the Lampyri, according to Matteucci, under similar circumstances.

Four tubes were filled with water containing the *Noctilucæ*. Into one oxygen was poured, into the second hydrogen, the third carbonic acid, the fourth chlorine. The first three gases produced the same effect, and not more than atmospheric air occasions through the agitation its passage causes. After half an hour these tubes were shaken with precisely the same result in all. Chlorine acted like other irritating agents; the light was at first bright and continuous, but rapidly became extinguished. Macaire and Matteucci have shown that the light of the Lampyri is immediately brightened in oxygen, and rapidly extinguished by carbonic acid. The light therefore cannot be alike in origin in the two cases.

11. *All physical agents that produce contractions cause phosphorescence, and in proportion to the intensity of the contractions.*—This conclusion was established by M. de Quatrefages by ex-

periments upon the influence of pressure, heat and electricity; of sulphuric, nitric, muriatic and hydrosulphuric acids; potash, ammonia, alcohol, æther, turpentine, common salt, Owen's liquid, milk, fresh water. With very dilute sulphuric acid, the excitation is strongly marked, attended with a rupture more or less rapid of the filaments uniting the interior mass to the envelope, and finally a detachment of the mass from the envelope, and a withdrawal towards its mouth. A portion of the inner mass and tissues may still cover the inner surface of the envelope; but after a while they come away from the envelope, and collect about the mouth, leaving the envelope empty. In the dark there is a very brilliant light at the first contact of the dilute acid with the *Noctilucæ*; then afterwards there appears a clear fixed white light on one part, which rapidly spreads, till the whole is like a ball of silver. The brilliancy soon after begins to diminish, and rather rapidly disappears. The rupture of the fibres and disorganization of the interior mass evidently take place consentaneously with the flashes and change in the light.

It is hardly necessary to cite the other experiments in this place. M. de Quatrefages concludes that the light is produced by the contraction of the interior mass of the body; that the scintillations are owing to the rupture and rapid contraction of the filaments of the interior, and that the fixed light which these animals emit before dying, proceeds from the permanent contraction of the contractile tissues adhering to the inner surface of the general envelope. The production of the light is independent of all material secretions. Whether it is accompanied by a discharge of electricity or not remains to be ascertained.

XXII.—*On some new Carboniferous Limestone Fossils.* By Frederick M'Coy, F.G.S., Hon. F.C.P.S., Professor of Mineralogy and Geology in the Queen's University of Ireland.

Pinna spatula (M'Coy).

Desc. Valves very narrow and much elongated, about four times larger than the width of posterior end, very slightly convex except at the beaks, which are pointed and almost cylindrical, the sides gradually flattening as they approach the posterior end, which is subtruncate or slightly rounded obliquely; cardinal margin slightly thickened, with the cartilage ridge very close within its edge; surface perfectly smooth, or with very faint laminar lines of growth parallel with the margins. Length of large, rather imperfect specimen $5\frac{1}{2}$ inches, proportional greatest width at posterior end about $\frac{30}{100}$, greatest depth $\frac{8}{100}$ or $\frac{9}{100}$.